STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF FACILITIES CONSTRUCTION
OFFICE OF TRANSPORTATION LABORATORY
and

District 2 Materials Section

EFFECTIVENESS OF RUBBERIZED ASPHALT IN STOPPING REFLECTION CRACKING OF ASPHALT CONCRETE
(Interim Report)

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16. ABSTRACT

A series of experimental rehabilitation techniques that include rubber-asphalt were constructed over an existing asphalt concrete pavement on Route 395 near Ravendale, California. The experimental sections consisted of a dense graded rubberized AC referred to as PlusRide, a dense graded rubberized AC prepared by the Arizona Refining Company ("ARS"), single and double chip seals using the ARS binder and a rubberized stress absorbing membrane interlayer (SAMI).

This report presents a description and discussion of the mixing, placing and performance to date of the mixtures. After one winter, all of the rubber mixtures are peforming better than the control sections of conventional asphalt concrete placed for comparison.

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NOTICE

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Neither the State of California nor the United States Government endorse products or manufacturers. Trade or manufacturers' names appear herein only because they are considered essential to the object of this document.

CONVERSION FACTORS

English to Metric System (SI) of Measurement

Quality	English unit	Multiply by	To get metric equivalent
Length	inches (in)or(")	25.40 .02540	millimetres (mm) metres (m)
	feet (ft)or(')	.3048	metres (m)
	miles (mi)	1.609	kilometres (km)
Area	square inches (in^2) square feet (ft^2) acres	6.432×10^{-4} .09290 .4047	square metres (m^2) square metres (m^2) hectares (ha)
Volume	gallons (gal) cubic feet (ft^3) cubic years (yd^3)	3.785 .02832 .7646	litre (1) cubic metres (m^3) cubic metres (m^3)
Volume/Time (Flow)	cubic feet per second (ft^3/s	28.317	litres per second 1/s)
	gallons per minute (gal/min)	.06309	litres per second (1/s)
Mass	pounds (lb)	.4536	kilograms (kg)
Velocity	miles per hour (mph) feet per second (fps)	.4470 .3048	metres per second (m/s) metres per second (m/s)
Acceleration	feet per second squared (ft/s^2)	.3048	metres per second squared (m/s^2)
	acceleration due to force of gravity (G) (ft/s^2)	9.807	metres per second squared (m/s^2)
Density	(lb/ft^3)	16.02	kilograms per cubic metre (kg/m^3)
Force	pounds (lbs) (1000 lbs) kips	4.448 4448	newtons (N) newtons (N)
Thermal Energy	British termal unit (BTU)	1055	joules (J)
Mechanical Energy	foot-pounds (ft-lb) foot-kips (ft-k)	1.356 1356	joules (J) joules (J)
Bending Moment or Torque	inch-pounds (in-lbs) foot-pounds (ft-lbs)	.1130 1.356	newton-metres (Nm) newton-metres (Nm)
Pressure	pounds per square inch (psi) pounds per square foot (psf)	6895 47.88	pascals (Pa) pascals (Pa)
Stress Intensity	kips per square inch square root inch ($ksi\sqrt{in}$)	1.0988	mega pascals$\sqrt{metre}$ ($MPa\sqrt{m}$)
	pounds per square inch square root inch ($psi\sqrt{in}$)	1.0988	kilo pascals$\sqrt{metre}$ ($KPa\sqrt{m}$)
Plane Angle	degrees (°)	0.0175	radians (rad)
Temperature	degrees fahrenheit (F)	$\frac{+F - 32}{1.8} = +C$	degrees celsius (°C)

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I. INTRODUCTION

The project is located on Route 395 (P.M. 92.0 - P.M. 101.4) about 40 miles northeast of Susanville (Figure 1).

The purpose of this research project is to evaluate the effectiveness of rubber-asphalt mixtures in stopping reflection cracking in dense graded asphalt concrete (DGAC) overlays of an existing AC pavement.

The various products involved in these overlay test sections are:

- ARS rubberized DGAC (ARS is the "logo" of Arizona Refining Company and is derived from "ARM-R-SHIELD", trade mark for their rubberized binder, which was used in the mix.)
- PlusRide rubberized DGAC (All Seasons Surfacing Company)
- Rubberized (ARS) stress absorbing membrane interlayer (SAMI) with DGAC overlay
- Rubberized (ARS) chip seals, both single and double

Test section layout and other details can be found in Table 1.

This report presents a description and discussion of the following items:

1. Layout of the project segments (Table 1).
2. Character and condition of the roadway before placement of the overlays.

02	Las	395	92.0/101.4	1	9

Chief, Office of Office Engineer
Registered Civil Engr. No. [illegible]

[illegible] April 11, 1983

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2	Typical Cross Sections and Quantity Summary
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6	Cable Anchor Assembly (Breakaway)
7	Roadside Sign Details
8	Traffic Control System
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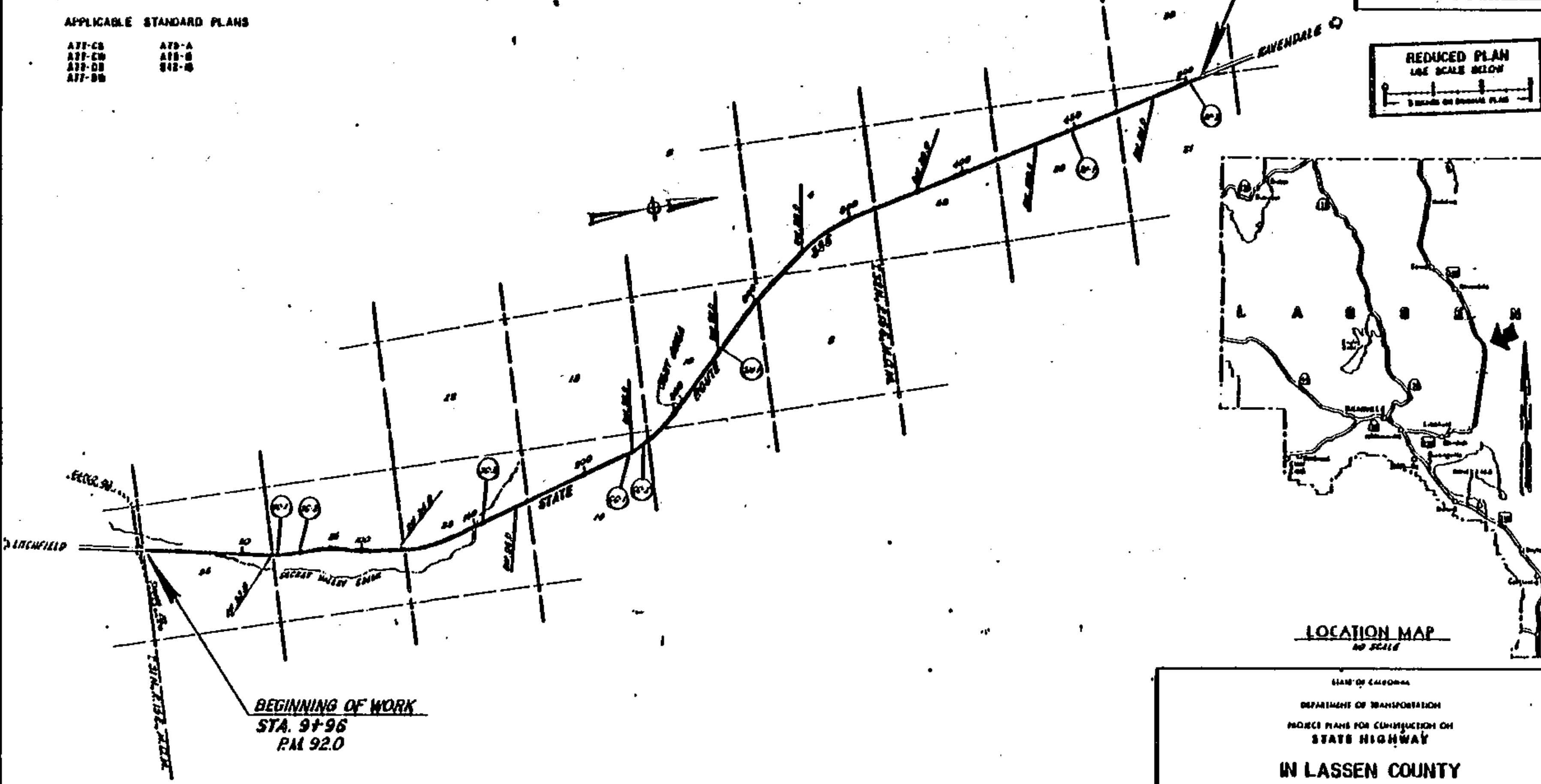
APPLICABLE STANDARD PLANS

A77-CB, A77-CD, A77-DB, A77-DD, A73-A, A73-B, S12-B



○ ENVIRONMENTALLY SENSITIVE AREA SEE PLAN SHEET FOR DETAILS.

LENGTH OF WORK = 9.4 MILES

0 — 5,000 — 10,000
SCALE IN FEET

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
PROJECT PLANS FOR CONSTRUCTION ON
STATE HIGHWAY

IN LASSEN COUNTY
FROM 0.5 MILE SOUTH OF SECRET VALLEY BRIDGE NO. 7-59 TO 7.0 MILES SOUTH OF RAVENDALE POST OFFICE

to be supplemented by Standard Plans dated January 1981

Contract No. 02-189504

02 206 189501

SEGMENT NUMBER	PM TO PM = MILES	WORK DONE
1.	92.00 - 93.00 = 1.00	0.25' of ARS DGAC over ARS SAMI
2.	93.00 - 95.00 = 2.00	0.15' of ARS DGAC over ARS SAMI
3.	95.00 - 95.15 = 0.15	0.15' of ARS DGAC
4.	95.15 - 95.30 = 0.15	0.15' of PlusRide DGAC
5.	95.30 - 97.30 = 2.00	0.15' of PlusRide DGAC over ARS SAMI
6.	97.30 - 98.30 = 1.00	0.25' of PlusRide DGAC over ARS SAMI
7.	98.30 - 98.45 = 0.15	0.15' of Conventional DGAC Control
8.	98.45 - 98.60 = 0.15	0.20' of Conventional DGAC Control
9.	98.60 - 98.75 = 0.15	0.30' of Conventional DGAC Control
10.	98.75 - 98.90 = 0.15	0.50' of Conventional DGAC Control
11.	98.90 - 99.90 = 1.00	Double Rubberized Chip Seal, Type 2 Binder
12.	99.90 - 100.90= 1.00	Double Rubberized Chip Seal, Type 1 Binder
13.	100.90 - 101.4= 0.50	Single Rubberized Chip Seal, Type 2 Binder

PROJECT SEGMENT DESCRIPTIONS

Table 1

3. Construction observations and cost comparisons.

4. Laboratory testing of the materials.

5. Physical characteristics of the materials.

6. Performance evaluation after one winter of service.

II. OBSERVATIONS AND CONCLUSIONS

° The ARS rubberized DGAC was mixed and placed without any significant problems.

° The PlusRide rubberized DGAC was mixed and placed with some difficulty, though, in the end, specifications were met.

° Laboratory tests generally indicate that the addition of rubber to DGAC significantly improves surface abrasion resistance.

° Asphalt binder content of rubberized DGAC mixes cannot reliably be determined by the conventional extraction procedures (Calif. TM310, or 362).

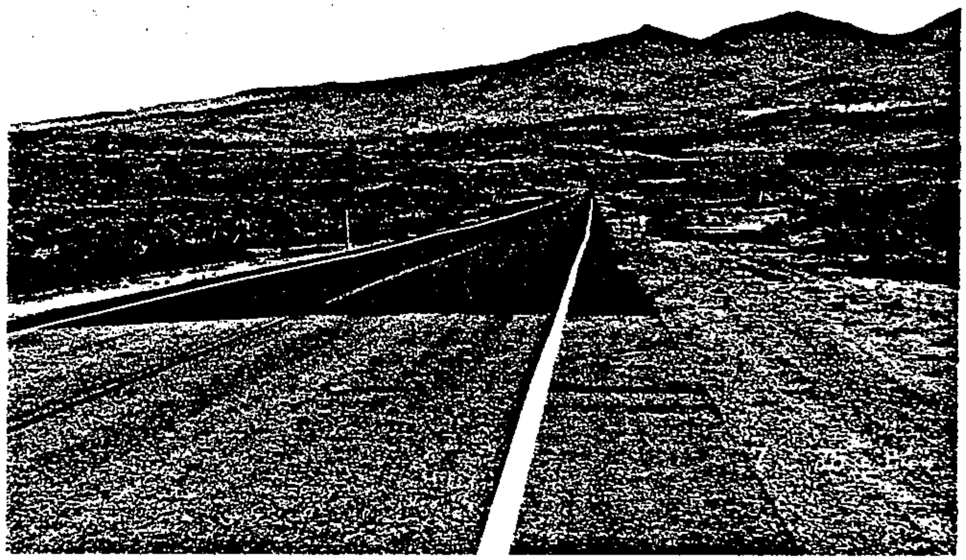
° After one severe winter of service, both the ARS DGAC and the PlusRide DGAC in relatively thin overlays over badly cracked old AC are in excellent condition, whereas some of the similar thickness conventional AC showed reflective cracking within three months after placement.

A Translab deflection study of this route segment, in May of 1982, indicated that a 0.70-foot-thick AC overlay, or equivalent, would be required for structural adequacy. Such an improvement would have been unreasonably expensive. Rubberized AC is purported to withstand large amounts of flexing without cracking, so it was decided to experiment with relatively thin rubberized AC overlays to stop the cracking instead of trying to meet the structural need.

This portion of Route 395 was originally built in three separate contracts. P.M. 98.44 to P.M. 101.38 was built in 1948. P.M. 96.50 to P.M. 98.44 was built in 1952 and P.M. 91.94 to P.M. 96.50 was built in 1954. In each case, the project was paved with 1-1/2 inches of road mix asphalt surfacing. The entire project has been resurfaced at least twice since original construction, most recently in 1970 when a 0.08 foot thin blanket overlay was placed.

B. Geography

The project is located in a remote part of northeastern California, in eastern Lassen County, about 40 miles northeast of Susanville and about 15 miles west of the Nevada border. It is a little over 100 miles north of Reno. The region is sparsely settled high desert (Figure 3). The project traverses a rocky valley between two



Route 395 - High Desert Region
Figure 2

mountain masses, Snowstorm Mountain on the west and Shinn Mountain on the east. Both rise about 2000 feet above the valley, which itself rises from about 4400 feet in elevation at its south end to about 5400 feet at its north end. The north end of the project is at a summit; the highway then descends in about 5 miles to the south edge of the desolate Madeline Plain, a large (over 20 miles across) Pleistocene lakebed with an elevation of about 5300 feet.

Most of the first 2-1/2 miles of the project is built on a low fill over alluvium, at least some of which may be moderately soft. All the rest of the project is built over or through solid or nearly solid Pliocene and Pleistocene basalt. What soil there is, is mostly in cracks in the rock. This lava varies from massive, with joints several feet apart, to very closely jointed , with joints only an inch or so apart. The vegetation includes grasses, brush (especially sagebrush), and juniper "trees".

C. Climate

Because the project lies between two mountains and varies so much in elevation, the average annual precipitation varies considerably. It ranges from a low of less than 8 inches at the south end to a high of over 12 inches near the middle. At the north end, the average is less than 10 inches.

Precipitation can be expected in every month of the year, but typically an inch or less each month. In the summer months, this is likely to all be in a single thunderstorm, lasting perhaps two or three hours or less.

Although the weather is very dry, the ground stays saturated with moisture all winter. Much of the time, this is frozen, and when it does thaw, evaporation is slowed by low temperature.

The climate is very harsh. Frost occurs every month of the year, and the high temperatures in summer exceed 90 degrees. From May through October, the diurnal temperature range averages nearly 40 degrees.

From November through April, when overcast weather is more likely, it averages nearly 20 degrees, and low temperatures may drop below zero.

D. Traffic

This portion of Route 395 is the main route between Reno and the Pacific Northwest. Reno has become a major warehouse center in recent years. There is a steady flow of a little over 100 five-axle trucks per day, all year long. The auto and light truck traffic is quite seasonal, however, so the overall traffic volume ranges from over 1400 vehicles per day in the summer and fall to only about 550 vehicles per day in the wintertime. The average annual daily traffic (AADT) is 1100 vehicles. The 10-year Traffic Index is 8.5, the 20-year T.I. is 9.5.

V. DISCUSSION

A. Preliminary Work (Prior to Construction)

1. Layout

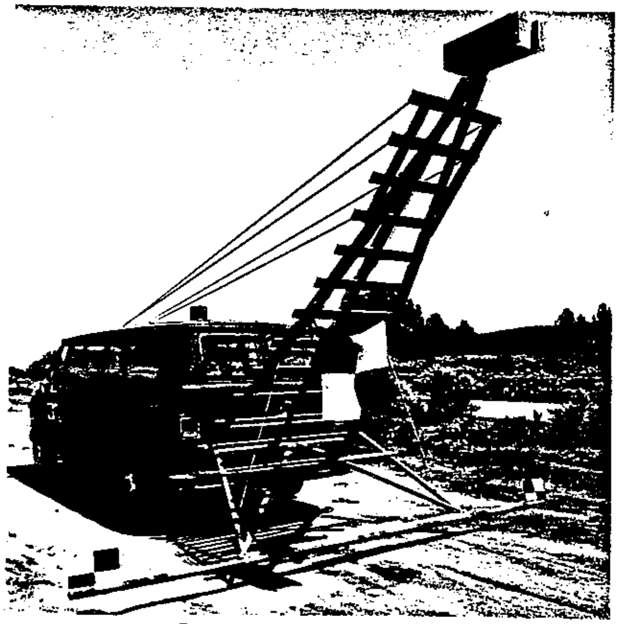
The project is arranged in 13 segments, each of which was given a different treatment, as shown in Table 1.

A 200-foot long, one-lane-wide test section was selected in the northbound lane for each segment. In Segments 2 and 5, each of which is two miles long, two test sections were selected, making a total of 15 test sections in the 13 project segments.

Each test section was laid out on the pavement and divided into 20 equally-spaced picture points (PP), each delineated by a "hash mark" painted on the paved shoulder and numbered so as to label and identify each photograph (Figure 3). The ends of each test section were referenced with steel survey pins set outside the planned limits of work to allow the test sections to be retraced exactly on top of the overlay after completion of the project.

The test sections were then photographed from 12.3 feet directly overhead at each picture point to record pavement condition, especially cracking, prior to the overlay work. This was accomplished by use of a District-designed and built camera boom mounted on the rear bumper of a 3/4-ton van (Figure 4). Each photograph covers a little more than 10 by 15 feet. Also, within each test section, an oblique photo was taken of a pole laid across the lane to record the amount and location of rutting

Photo "Hash" Marks on Pavement
Figure 3


Camera Boom
Figure 4

The test sections were placed in the northbound lane to avoid having the shadow of the camera boom in the pictures. The northbound lane also is subject to the most chain wear. Because it is the uphill lane throughout the project, every test section is upgrade (Table 2 - Column 1).

2. Rutting

Prior to construction, rutting in the wheel tracks averaged about 0.60 inch and ranged from a minimum of 0.25 inch (TS 2B and 11) to a maximum of 1.50 inches (TS 5a). This rutting appears to correlate fairly well with the calculated total gravel equivalent of the existing structural section. It does not seem to have resulted from instability in the old AC (Table 2 - Columns 9 and 10).

3. Cracking

Pavement cracking on the project was very extensive but by no means uniform. A Mylar overlay was made with a grid inked on it covering the photo of the 12-foot wide, 10-foot long sections of pavement depicted in each photograph (3-1/2" x 5-1/2" "jumbo" print), thereby dividing the 120 square-foot area into 20 equal 6 square-foot "squares" each 2 by 3 feet. The grid was then placed over each picture and "cracks counted", observing the arbitrary convention that each square with one or more cracks anywhere within it was "counted" as cracked. This process produced a "crack count" number ranging from 0 to 20 for each picture. These numbers were averaged for the 20 pictures covering each test section. That average was then multiplied by 5 to give an accurate percentage of the pavement area

Column Number

TEST SECT.	IN SEGMENT	(1) % of Grade (All) (+)	(2) ASB Thkn. (ft.)	(3) ASB "R" Val.	(4) ASB Sand Equiv.	(5) AB Thkn. (ft.)	(6) AB "R" Val.	(7) AB Sand Equiv.	(8) Exist AC Thkn. (ft.)	(9) Calc. Exist Total G.E. (ft.*)	(10) Rutting (in.)	(11) % of Pvmt. Area Crkd.
1	1	0.39	0.85	72	27	0.50	81	54	0.45	1.94	0.40	33
2A	2	1.25	0.95	56	17	0.35	83	47	0.50	1.94	0.40	63
2B	2	6.00	0.95	73	27	0.25	83	45	0.60	1.95	0.25	89
3	3	4.85	0.93	60	21	0.40	78	42	0.47	1.93	0.40	15
4	4	4.36	1.16	71	35	0.26	78	33	0.28	1.78	0.40	8
5A	5	3.25	0.77	80	27	0.53	83	40	0.30	1.71	1.50	73
5B	5	5.45	0.87	80	29	0.43	79	43	0.30	1.70	0.75	94
6	6	0.02	0.82	80	27	0.48	82	42	0.38	1.80	0.40	52
7	7	0.23	1.10	83	34	0.37	84	39	0.33	1.90	1.25	100
8	8	3.82	1.13	80	47	0.34	84	40	0.33	1.90	0.50	74
9	9	3.82	0.96	82	37	0.46	85	43	0.38	1.92	0.40	83
10	10	3.82	1.05	80	45	0.52	75	59	0.33	2.02	0.50	100
11	11	0.05	0.77	78	40	0.57	82	55	0.36	1.83	0.25	57
12	12	4.00	1.08	74	29	0.40	78	55	0.42	2.02	0.50	74
13	13	0.88	1.00	78	38	0.40	78	50	0.30	1.80	0.75	100

*Based on a basement soil "R" Value of 36, the lowest found and a 20-year T.I. of 9.5, the required G.E. for structural adequacy is 1.95 ft.

NOTE: "ASB" = Aggregate Subbase, "AB" = Aggregate Base.

EXISTING PAVEMENT AND SUBGRADE DATA

TABLE 2

that was cracked. Test Section 1, for example, had individual counts ranging from 0 to 13, the average for the 20 pictures is 6.60, which is 5 x 6.60 = 33% cracked. The 15 test sections range from a low of 8% cracked (TS 4) to a high of 100% cracked (TS 7, 10 and 13) with an average 68% cracked (Table 2 - Column 11).

By chance, the existing pavements in Segments 3 and 4, (the two with a rubberized AC overlay <u>without</u> a SAMI) were by far the least cracked segments of the project (Table 2 -Column 11). If it should happen that Segments 2 and 5 do <u>not</u> crack, and Segments 3 and 4 <u>do</u> crack, there would be a persuasive argument for the use of the SAMI, but the reverse will <u>not</u> be true, since Segments 3 and 4 had so little cracking before being overlaid.

The photographs represent a permanent record of the nature and appearance of the cracking and with monitoring over the years will also indicate visual rate of cracking.

4. Structural Section

Test holes were cut through the pavement and dug through the base and subbase material in PP 10 of each test section to inventory thicknesses and to obtain samples of the base and subbase material for laboratory testing. The existing AC averaged 0.38' thick, the aggregate base (AB) averaged 0.41' thick, and an average of 0.96' of aggregate subbase (ASB) was found (Table 2, Columns 2, 5 and 8).

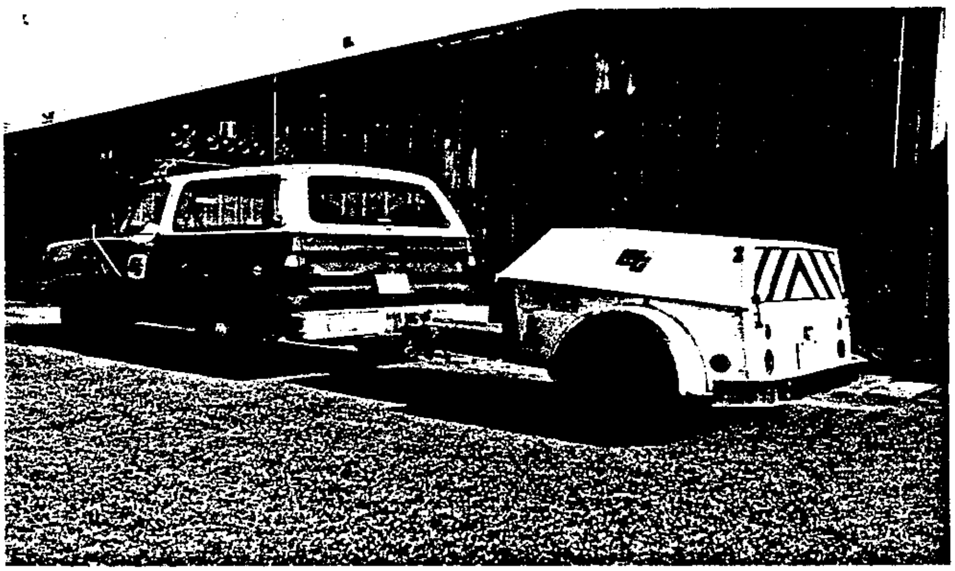
Both the AB and ASB have good "R" values, averaging 81 and 75, respectively (Table 2 - Columns 3 and 6).

The calculated gravel equivalent (GE) of this average structural section is 1.88'. Of the 15 locations sampled, the lowest calculated GE is 1.70, the highest 2.02 (Table 2 - Column 9). A gravel factor of 1.20 was assigned to the old AC for these calculations.

If a new structural section were being designed for this project, a GE of 1.95 would be required, based on the 20-year T.I. of 9.5 and basement "R" value of 36. This suggests that the structural section in place, in some areas at least, may not have been adequate for the current 20-year traffic Index.

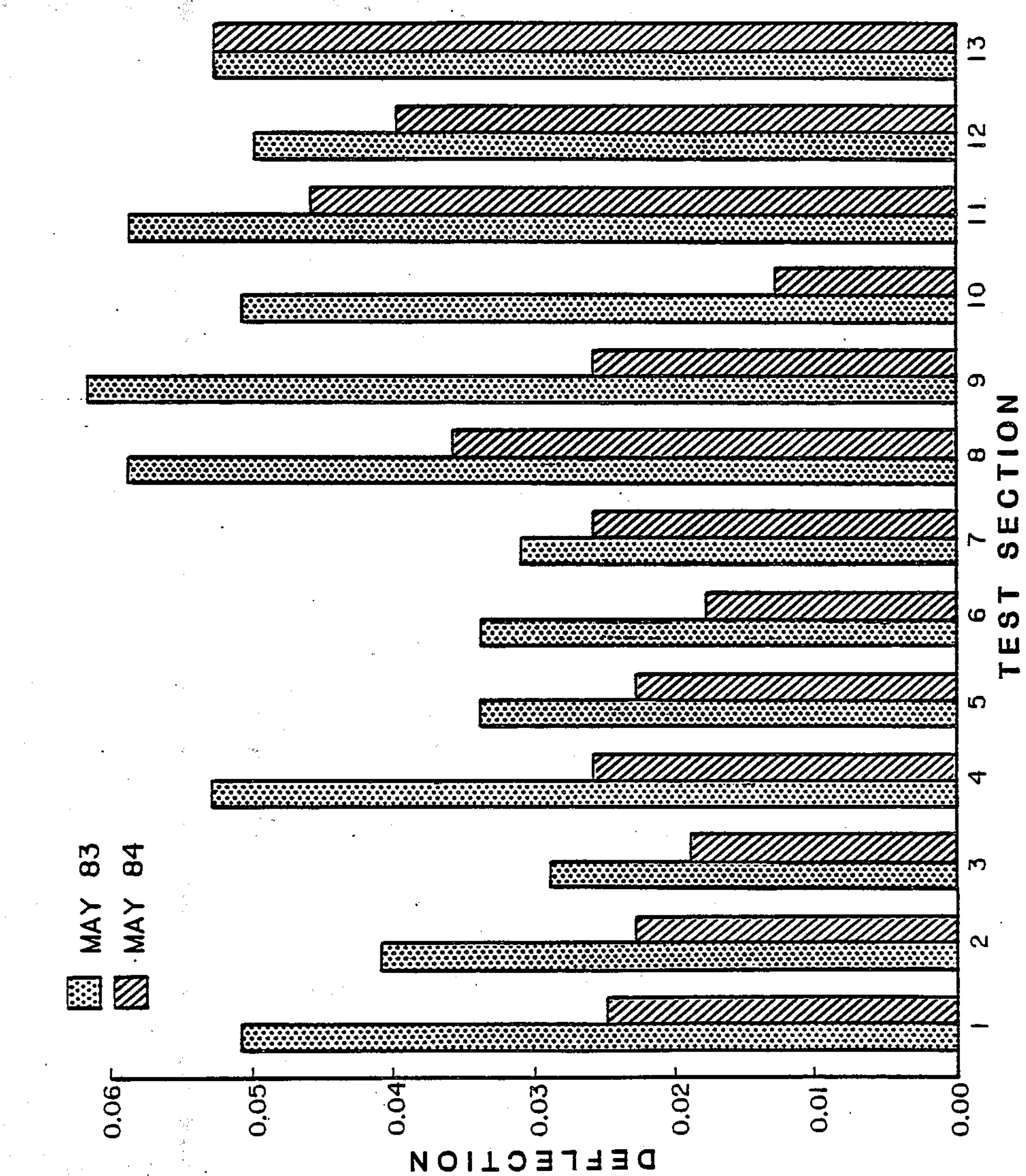
5. Deflections

A continuous deflection study of the entire project was made in May of 1983 (Figure 5). Deflections were measured each hundredth of a



Dynaflect - Used to Measure Pavement Deflection

Figure 6



PAVEMENT DEFLECTIONS

mile in both directions using a Dynaflect (Figure 6). Northbound andsouthbound lane values were carefully compared and found to be not significantly different. The southbound lane average values for entire project segments were then compared with the averages for the test sections alone. The test section values were found to be fairly representative. These ranged from a low of 0.023" (TS 7) to a high of 0.063" (TS 9) and averaged 0.043". These are Equivalent Deflectometer values and are considerably in excess of the "tolerable" deflection of 0.017" (Table 5 - Column 1).

B. Construction Observations

1. General

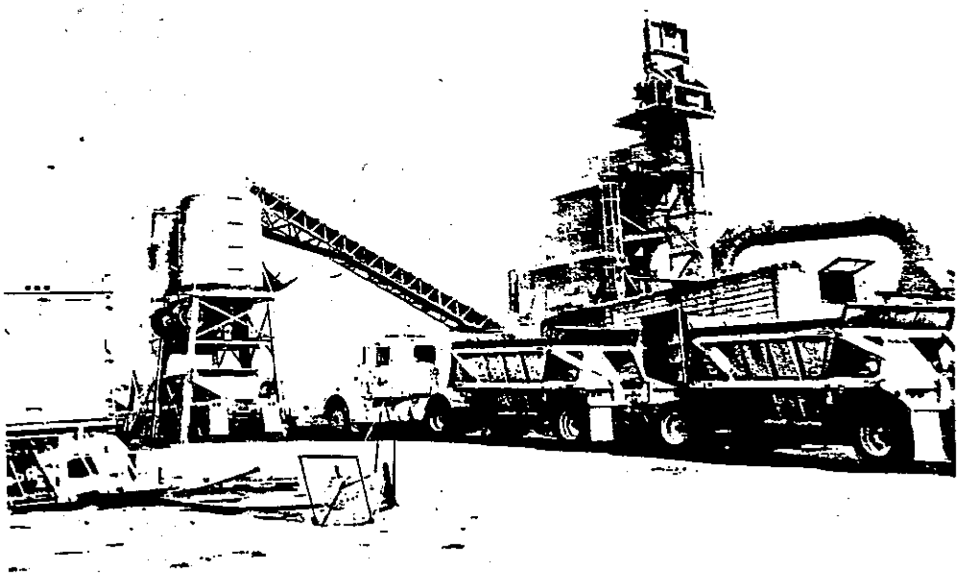
The project, Contract No. 02-189504, was built in August and September of 1983. The Resident Engineer was Miles Skinner. Frank W. Pozar of Fresno, California was the contractor. Ben Coker was the Street Inspector and Willie Fisher the Plant Inspector for Caltrans. Norm Peterson was the Arizona Refining Company ("ARS") representative on the project. All Seasons Surfacing Corporation, of Bellevue, Washington, owners of the PlusRide process, were represented on the project by Bob Linden. Specific details of the various rubberized treatments are found in Appendix A.

Mix design for the ARS and PlusRide AC products was done by ARS (Norm Peterson) and All Seasons, (Bob Linden), respectively, to assure that the materials, as placed, would be fully acceptable to them. The rubber asphalt binder for the SAMI's was also provided by ARS.

Mineral aggregate for the project was obtained from a commercial source, Miller Custom Works, located within a mile of the plant site, about 15 miles south of the project alongside Route 395.

Huntway AR 4000 asphalt from Martinez, California, was used on the project. Vulcanized reclaimed rubber came from Genstar and devulcanized reclaimed rubber came from U. S. Rubber Reclaiming Company.

The plant (Figure 7) was a Standard 10,000 pound capacity batch plant located on Route 395 about 15 miles south of the project (P.M. 78.50). AC mix was hauled from the plant



Batch Plant (10,000 lb capacity)
Figure 7

job in belly-dump trucks and windrowed ahead of the paver. It was then picked up by a Ko-Cal pickup machine and placed into a Blaw-Knox PF-180 paver with a 20-foot ski for grade control. Breakdown was accomplished with a Dynapac CC50A vibratory roller operating at maximum amplitude and maximum frequency of vibration, (2400 vpm). A Hyster C350 was used for finish rolling.

AC material 0.15-foot and 0.20-foot thick was placed in a single lift. Material 0.25-foot thick was placed in two lifts, the first 0.13 foot, the second 0.12 foot. Material 0.30-foot thick was placed in two 0.15-foot lifts, and 0.50 foot thick material in three lifts, a 0.20 foot lift followed by two lifts of 0.15 foot.

2. ARS-DGAC

The asphalt-rubber binder (Type 2) used in the ARS-DGAC, the ARS SAMI's and in the rubberized chip seal placed in Segments 11 and 13 was proportioned 78% AR-4000 asphalt, 18% ground reclaimed rubber and 4% Witco (Golden Bear) extender oil by weight. The rubber used was a blend of 20% devulcanized and 80% vulcanized reclaimed rubber. This rubberized binder was added to the aggregate in the pugmill at the rate of 8% of the weight of the dry aggregate.

The ARS-DGAC mix contained a normal AC mineral aggregate. The rubber was first blended with the asphalt and then held in a special blending or mixing tank at about 350°. Within the tank, there was no mechanical mixing other than circulation. The mixture was circulated for 45$\pm$ minutes and then placed in the contractor's regular asphalt storage tanks. From this point, the binder was treated the same as conventional asphalt in the preparation of the mix.

ARS prepared all the rubber-asphalt binder on the job site using their own special blending tanks and equipment. However, they were unable to provide a constant supply due to the 45 minute recirculation period required to homogenize the asphalt and rubber mixture. Occasionally, plant operations were shut down for short periods awaiting a new batch of binder. Blending equipment with the capacity to maintain a continuous supply of binder would have prevented this problem. This mix was placed with no difficulty.

ARS product (Figure 8) can be produced by a dryer-drum plant equally well, though with the same need for an adequate rate of

ARS Mix - P.M. 92.26

Figure 8

supply of mixed binder. This binder cannot be mixed much in advance as it must be used within 48 hours of mixing.

3. PlusRide Material

The PlusRide product (Figure 9) placed in Segments 4, 5 and 6 is another rubberized DGAC. It contains larger rubber particles as part of the dry aggregate. This requires that the mineral aggregate be "gap graded". This is often difficult to do, and on this project, considerable waste was generated in attaining the gap grading. The final aggregate gradation, however, was still somewhat deficient in the passing No. 200 fraction (after processing to a gap grading, only 5.0% passing No. 200 was available). All Seasons representative Bob Linden ultimately established that with the addition of 4.7% pozzolan, the required grading (8% to 12% passing the 200 screen), could be achieved.

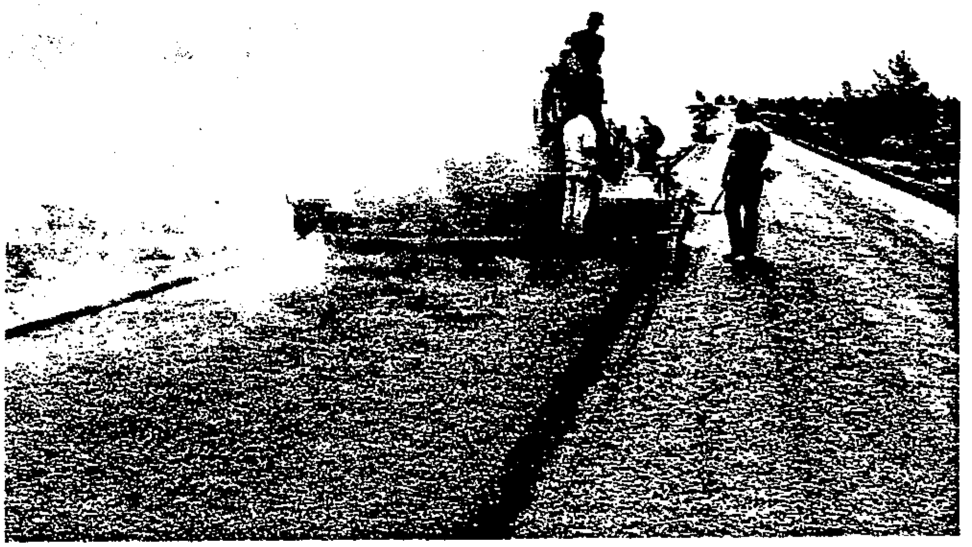
PlusRide Mix - P.M. 97.66

Figure 9

Rubber was added at the plant by two laborers who, at a whistle signal, dumped four 60-pound plastic bags into the pugmill for each 8000-pound batch, giving the mix 3.0% rubber (based on total mix weight). The rubber and dry aggregate were dry-mixed in the pugmill for 20 seconds before the asphalt was added. The material was then given the usual 30-second mix.

The mix had a tendency to stick to the conveyor belt as it was transported from the pugmill to a pair of storage tanks.

Loaded into the truck, and even in the windrow, the PlusRide mix was seen to quiver like gelatin. Tarps were not used on the 15-mile haul, as only 5 or 10 degree heat loss resulted. At the laydown temperature of up to 380° F, the paving operation was very smoky (Figure 10).



PlusRide Mix at 370°F

Figure 10

There were problems attaining the compaction specified by All Seasons Surfacing (96% of theoretical maximum density) for the PlusRide. At first, relative density values as low as 90% were measured (Segment #6). After the asphalt content was reduced from 9.65% to 9.41% (based on dry weight of the aggregate) and the proportion of pozzolan filler was adjusted to 4.7%, compaction then resulted in a relative density of 96% or greater. Part of the compaction problem resulted from the breakdown roller getting on the mix too soon (while it was still above 300°F).

Although this was as specified, waves were created ahead of the roller, and the mix tended to stick to the roller drums. After the mix was changed, as described above, breakdown rolling could be started at temperatures up to 285°F without problems. Thus it appears that the minimum 300°F specified breakdown temperature is excessive.

The PlusRide mix on this project is very different from ordinary DGAC and quite different from the ARS-DGAC mix. It has more than twice the rubber content of the latter and half again as much asphalt. While hot, it has the consistency of bubble gum, and after compaction, still feels springy underfoot. Both contractor and Resident Engineer noted that the mix was difficult to rake because it was sticky. The result was extreme difficulty in preparing construction joints. Although this project did not require tapers, in the opinion of the Resident Engineer, construction of a taper would have been a near impossibility with this mix.

4. Conventional AC

In Segments 7, 8, 9 and 10, the conventional DGAC, was placed without difficulty. It was a standard 3/4 inch maximum medium graded Type "A" AC. The mix design called for 4.2% to 4.6% asphalt.

5. Cost Comparison

A comparison of the contractor's costs, (NOT the bid prices), for the various items of work is presented in Table 3. These are in-place costs, calculated as for extra work. About 7000 tons of each kind of AC was made.

6. Rubberized Chip Seals

A rubberized chip seal surfacing, also known as a stress absorbing membrane (SAM) differs from a conventional chip seal by utilizing a rubberized binder and pre-heated, pre-coated chips. Both Segments 11 and 12 have double rubberized chip seals. Segments 11 and 13 have Type 2 Binder and Segment 12 has a Type 1 Binder. These two similar rubberized binders were used to compare their performance. The Type 1 Binder is as specified by Sahuaro Petroleum Company, who owned the PlusRide patents when this project was designed, and the Type 2 Binder is the ARS (Arizona Refining Company) specification. ARS produced both kinds of binder for this project. Sahuaro had in the meantime sold the PlusRide patents to All Seasons Surfacing Company. (See Appendix A for the project special provisions covering, among other things, these binders.)

A thin leveling course of 1/2-inch conventional DGAC was bladed onto Segments 11, 12 and 13 to fill cracks and correct the crown of the roadway before applying the rubberized chip seals to these segments. The chip seals went down with a minimum of difficulty -- the principal problem was that the rubberized asphalt binder smoked so heavily when sprayed from the distributor that it was difficult to see how well each spray nozzle was working. Some nozzles were not working well and the finished chip seals had a streaked appearance. On the double seals, there was at least one longitudinal "groove"

SEGMENT NUMBER	DESCRIPTION	$COST* (Square Yard)
1	0.25' of ARS DGAC over ARS-SAMI	10.41
2	0.15' of ARS DGAC over ARS-SAMI	6.88
3	0.15' of ARS DGAC	5.37
4	0.15' of PlusRide DGAC	6.32
5	0.15' of PlusRide DGAC over ARS-SAMI	7.83
6	0.25' of PlusRide DGAC over ARS-SAMI	12.00
7	0.15' of Conventional DGAC Control	3.04
8	0.20' of Conventional DGAC Control	4.03
9	0.30' of Conventional DGAC Control	6.02
10	0.50' of Conventional DGAC Control	9.99
11	Double Rubberized Chip Seal, Type 2 Binder	2.60
12	Double Rubberized Chip Seal, Type 1 Binder	2.62
13	Single Rubberized Chip Seal, Type 2 Binder	1.56

*Contractor's in-place cost; not necessarily the bid price.

TABLE 3 - COST DATA

where a nozzle sprayed weakly in both layers. The preheated, precoated chips adhered well. The coverage appeared complete, although variable in thickness, and resulted in a dense, even surface texture.

Spread rates for the double chip seals were: first spread, binder, 0.50 gal/sy, chips, 34 lbs/sy; second spread, binder, 0.50 gal/sy, chips, 26 lbs/sy. Set times ranged from two to 24 hours before brooming and chip retention after brooming was 95%. The single chip seal spread rates were: binder, 0.60 gal/sy, chips, 35 lbs./sy. Set times ranged from 2 to 24 hours before brooming and chip retention after brooming was 92%. The spread rates for the SAMI were the same as for the single chip seal, but chip retention after brooming was 95% according to the Resident Engineer.

7. Post-Construction Work

In October 1983, immediately after construction was completed, test section limit marks were retraced on the new surface and repainted. Although the weather was cold, (about 40°F), 2-1/2-inch pavement nails could be driven into the rubberized AC in Segments 1 through 6 with some effort but readily enough. The conventional DGAC in Segments 7 through 10 was very different. This mix would chip and flake and the nails would bend or break.

Three 8-inch diameter cores were then cut in picture point 1 of Test Sections 1 through 10 to determine thickness, density, asphalt content and grading. Using pre-construction data, one core was taken at the low point of each wheel track rut and one at the high point between wheel tracks. Cores 4 inches in diameter were taken from picture point 2 of Test Sections 1 through 10 specifically to test for surface abrasion (Calif. TM360). In Test Sections 11, 12 and 13, 4-inch cores were cut, three per TS, for thickness only.

C. Materials Testing

1. Thickness

Table 4 compares planned and as-built thicknesses in each of the Test Sections, (the average of three cores in each case). In TS 1, 2A and 2B differences are slight to none, but TS 3 is 20% thinner than planned. TS 4 and 5A are 27% and 33% thicker than planned, while 5B and 6 are exactly the planned thickness. TS 7 is 33% thicker than planned, while TS 8, 9 and 10 are very close to the planned thickness. It seems reasonable to suppose that differences of 20% or more might produce significantly different performance than the planned thickness.

2. Compaction

The data shown in Column 5 of Table 5 represent the percent compaction in relation to the maximum theoretical density. The value tabulated is the average of the three cores in each test section. Both the ARS-DGAC and the conventional DGAC compactions were about 92%, which is considered normal for DGAC. The PlusRide DGAC consistently met or exceeded the specified 96% compaction.

TEST SECT.	(1) As-Built Overlay Thkn. (ft.)	(2) Total Planned Thkn. (ft.)	(3) Planned AC Overlay Thkn. (ft.)	(4) Approx. Thkn. of SAMI* Or SAM (ft.)	(5) Differ. As-Built Minus Planned Thkn. (ft.)	(6) Differ. As a % of Planned Thkn. (ft.)	(7) As-Built AC Thkn. (Not Incl. (SAMI) (ft.)	(8) As-Built Gravel Equivalent (8.5 T.I.)
1	0.27	0.28	0.25	0.03	-0.01	-4	0.24	0.45
2A	0.18	0.18	0.15	0.03	None	None	0.15	0.28
2B	0.16	0.18	0.15	0.03	-0.02	-11	0.13	0.25
3	0.12	0.15	0.15	None	-0.03	-20	0.12	0.23
4	0.19	0.15	0.15	None	+0.04	+27	0.19	0.36
5A	0.24	0.18	0.15	0.03	+0.06	+33	0.21	0.40
5B	0.18	0.18	0.15	0.03	None	None	0.15	0.28
6	0.28	0.28	0.25	0.03	None	None	0.25	0.47
7	0.20	0.15	0.15	None	+0.05	+33	0.20	0.38
8	0.18	0.20	0.20	None	-0.02	-10	0.18	0.34
9	0.32	0.30	0.30	None	+0.02	+7	0.32	0.60
10	0.52	0.50	0.50	None	+0.02	+4	0.52	0.99
11	0.10	0.04	None	0.04	+0.06	+150	0.06	0.07
12	0.13	0.04	None	0.04	+0.09	+225	0.09	0.11
13	0.14	0.03	None	0.03	+0.11	+367	0.11	0.14

* Stress Absorbing Membrane Interlayer

OVERLAY THICKNESS DATA
TABLE 4

TEST SECTION	BEFORE (1) May 1983 Deflects. (0.001")	AFTER CONSTRUCTION (2) May 1984 Deflects. (0.001")	(3) Percent Reduction in Deflect.	(4) Calc. As-Built Total G.E.† (TI=8.5) (Feet)	(5) New A.C. Percent Compact.*(	(6) New Permea-bility ml./min.)	(7) New A.C. Surface Abrasion (Method B) (gm. loss)	(8) Oct. 1983 Skid No. (SN 40)	(9) May 1984 Skid No. (SN 40)
1	54	26	52	2.45	93.3	36.3	17.1	55	54
2A	37	21	43	2.29	92.2	22.3	15.0	58	57
2B	49	29	41	2.25	90.9	N.T.	18.1	55	54
3	25	16	36	2.15	92.8	N.T.	18.7	54	52
4	55	27	51	2.14	97.1	N.T.	9.7	39	51
5A	34	27	18	2.17	98.4	11.0	12.2	36	46
5B	27	25	7	2.04	98.5	N.T.	17.4	43	50
6	27	16	41	2.34	96.1	6.8	11.4	44	55
7	23	18	22	2.28	91.7	177.0	47.8	66	57
8	60	44	27	2.24	91.2	N.T.	48.2	68	58
9	63	28	56	2.53	91.4	N.T.	32.5	65	58
10	46	13	72	3.01	92.1	N.T.	35.1	67	55
11	44	42	5	1.90	N.A.	N.T.	N.A.	62	60
12	51	35	31	2.13	N.A.	N.T.	N.A.	59	56
13	54	52	4	1.94	N.A.	N.T.	N.A.	57	59

*Core bulk specific gravity   Rice (ASTM D 2041) Specific Gravity X 100.
NOTE: "N.A." means Not Applicable; "N.T." means Not Tested.
† Gravel Equivalent.

OVERLAY EVALUATION DATA
TABLE 5

3. Permeabilities

Although grease ring permeability tests (Calif. TM 341) were run on the AC test sections, the permeability of the rubberized chip seals could not be obtained due to the inability to form the required watertight seal on the chips. The PlusRide DGAC proved to be virtually impermeable, and the ARS-DGAC nearly so. The conventional DGAC was very permeable (Table 5 - Column 6).

4. Surface Abrasion Loss (Calif. TM360B)

Based on surface abrasion test results (Table 5 - Column 7), it appears that the rubberized binder in the ARS-DGAC and the rubber incorporated in the PlusRide DGAC protect the mineral aggregate from abrasion. On this basis, the rubberized material could be expected to have a high resistance to chain wear in winter. The average measured values for each material were as follows:

ARS DGAC --------------17 g

PlusRide DGAC ----------13 g

Conventional DGAC ------41 g

It is generally felt that values greater than about 35 grams indicate problem mixes.

5. Extractions

There was reason (reports from Translab) to expect that asphalt extraction tests (Calif. TM310) of the rubberized AC mixes might not be successful. In Translab tests, rubber had not dissolved completely enough, in either the asphalt or the extraction solvent, to avoid clogging the filters. Also, rubber that dissolves in the solvent is indistinguishable from asphalt. If extraction results differ from the designed amount there is always the possibility of plant batching errors as well. Asphalt contents determined by extraction tests on these mixes generally were higher than designed values. In the case of the conventional AC mix this was easily explained by the practice of District 2 resident engineers routinely calling for slightly more asphalt than the recommended amount. In the case of the rubberized mixes, whose binder content was directed by the engineers (and had no lab design) representing the owners of the processes, the explanation is not so easy.

Two extractions, one each of ARS (TS 1) and PlusRide (TS 5A) were done in the District 2 Lab. These indicated 6.4% and 10.4% "asphalt", respectively. Translab test results are shown below.

Asphalt Content *(Calif. TM310)

Type of Mix	Theoretical Design Lab	Theoretical Design Field	Extraction Average	Extraction No. of Core Samples
ARS (TS 1-3)	___	6.6	6.8	12
PlusRide (TS 6)	___	9.6	11.0	3
PlusRide (TS 4, 5A & 5B)	___	9.4	9.9	9
Conventional DGAC (TS 7-10)	4.5	5.0	4.7	12

*Not including rubber.

It appears from the above data in that either part of the rubber in the rubberized mixes dissolved in the extracting solvent or there were plant batching errors. In the former case, any filter plugging with rubber must not have been enough to prevent complete extraction of the asphalt plus part of the rubber. If the filter clogs completely and early enough, not all the asphalt will be extracted and the extracted asphalt will indicate <u>less</u> than the theoretical

SIEVE SIZE	PERCENT PASSING								
	ARS (TS 1)		PLUSRIDE (TS 5A)		CONVENTIONAL AC				
					EXTRACTED				
	EXTRACTED	SPEC.	EXTRACTED	SPEC.	TS 7	TS 8	TS 9	TS 10	SPEC.
1"								100	100
3/4"	100	100			100	100	98	100	95-100
5/8"			100	100					
1/2"	97	95-100	89		79	86	82	84	
3/8"	80	80-85	63	60-80	70	72	69	75	65-80
1/4"			47	30-50					
#4	57	55-65	36		48	51	46	53	46-56
#8	44	38-48	25		35	38	35	40	33-43
#10			23	19-32					
#30	25	18-28	17	13-25	21	23	21	23	14-24
#100	10		11		10	11	9	11	
#200	7	3-8	8	8-12	7	8	6	8	3-8

TS = Test Section

TABLE 6. AGGREGATE GRADATION DATA

amount. Obviously, at this point all that can be said is that the asphalt binder content of rubberized AC mixes cannot reliably be determined by the conventional hot extraction procedure.

The aggregate gradations determined from the cores (after extractions) are compared to the specification requirements in Table 6. These after-extraction gradations complied with the gradation specfications. Good uniformity of production is illustrated by the extracted gradings of the conventional mix in Test Sections 7, 8, 9 and 10. The PlusRide utilized a special gradation that varied, during production, from 8-12% passing the No. 200 sieve. The ARS mix utilized California's aggregate gradation specification for conventional 1/2" max medium asphalt concrete.

6. Skid Numbers

In October of 1983, skid tests were run on each of the 15 test sections using the Towed Trailer Skid Tester (Figure 11).

Towed Trailer Skid Tester
Figure 11

The conventional DGAC in TS 7 through 10 had exceptionally high skid numbers (SN 40), averaging 66.5. The ARS-DGAC in TS 2 through 3 had good skid numbers, averaging 55.5. The PlusRide DGAC in TS 4 through 6 had adequate skid numbers, averaging 40.5. The rubberized chip seals in TS 11, 12 and 13 had very good skid numbers, which averaged 59.3 (Table 5 - Column 8).

In May of 1984, the skid tests were rerun to find what time, weather and traffic had done to the surfaces. (Chains are frequently necessary on vehicles climbing the grade through the project in the wintertime.) The ARS DGAC and the rubberized chip seals were virtually unchanged, averaging 54.3 and 58.3, respectively. The PlusRide DGAC showed a 10-point increase to an average of 50.5, and the conventional DGAC, a 10 point decrease to an average of 57.0 (Table 5 - Column 9). The surface glaze on the PlusRide material had when it was new was now gone. The improvement in skid numbers is no doubt related to this. It was also observed that the conventional DGAC had lost quite a bit of fines from its surface and the decrease in its skid numbers may have been the result.

These skid test data are summarized below.

	October 1983	May 1984
ARS-DGAC	55.5	54.3
PlusRide DGAC	40.5	50.5
ARS Chip Seal	59.3	58.3
Conventional DGAC	66.5	57.0

7. Deflections

Another Dynaflect study of the northbound lane through the project was done in May of 1984 (Figure 6). Again, the test sections were found to be fairly representative of the full segments (Table 5 - Column 2). Column 3 of Table 5 shows the percentage reduction in deflections resulting from the work performed.

Table 7 shows the results of an analysis of the observed deflection reductions compared to the expected reductions for conventional AC overlays of the as-built thicknesses of overlay in each test section. This analysis utilized Figure 13 of the Caltrans AC Overlay Design Manual. The ARS overlays reduced deflections more than expected, the PlusRide overlays reduced deflections, on average, less than expected, and the conventional AC overlays about as expected, average. Inferred Gravel Equivalents and Gravel Factors were

TEST SECT.	(1) Calc. Exist. G.E. Equiv. (ft.)	(2) As-Built AC Ov'lay Thkn. (ft.)	(3) Calc. G.E. Incr. (ft.)	(4) Expect. Reduct. In Deflects. (%*)	(5) Meas. Reduct. In Deflects. (%)	(6) Inferred G.E. From Meas. % Reduct. (ft.*)	(7) G_f for Inferred G.E. to Be Correct (6 - 2)
1	1.94	0.24	0.45	41	52	0.82	3.42
2A	1.94	0.15	0.28	34	43	0.50	3.33
2B	1.95	0.13	0.25	33	41	0.45	3.46
3	1.93	0.12	0.23	31	36	0.32	2.67
4	1.78	0.19	0.36	38	51	0.80	4.21
5A	1.71	0.21	0.40	40	18	0.08	0.38
5B	1.70	0.15	0.28	34	7	0.03	0.20
6	1.80	0.25	0.47	41	41	0.45	1.80
7	1.90	0.20	0.38	39	22	0.12	0.60
8	1.90	0.18	0.34	37	27	0.18	1.00
9	1.92	0.32	0.61	46	56	0.98	3.06
10	2.02	0.52	0.99	56	72	1.57	3.02
11	1.83	0.06	0.07	13	5	0.02	0.33
12	2.02	0.09	0.11	21	31	0.22	2.44
13	1.80	0.11	0.14	25	4	0.02	0.17

*From Figure 13 in A.C. Overlay Design Manual

TABLE 7. DEFLECTION REDUCTION ANALYSIS

calculated, again using Figure 13 of the AC Overlay Design Manual. These suggest that the ARS mix may be quite a bit stiffer than conventional AC, and that the PlusRide mix is not quite as stiff as conventional AC.

At this time it is not known how to interpret deflections of rubberized AC pavements. It can be argued that the rubber admixture might increase the tensile strength of the binder, and makes the mix stiffer; it can be argued equally well that the rubber admixture increases the elasticity of the binder and makes the mix more flexible. In this case, the ARS mix, with about 1.4% rubber, seems stiffer and the PlusRide mix, with about 3% rubber, seems more flexible. Beyond this, the intent of the rubber admixture is to increase the amount of deflection the mix will <u>tolerate</u> without cracking, and, of course, it is the purpose of this study to determine if this is so. The more flexible material may well tolerate the most deflection without cracking.

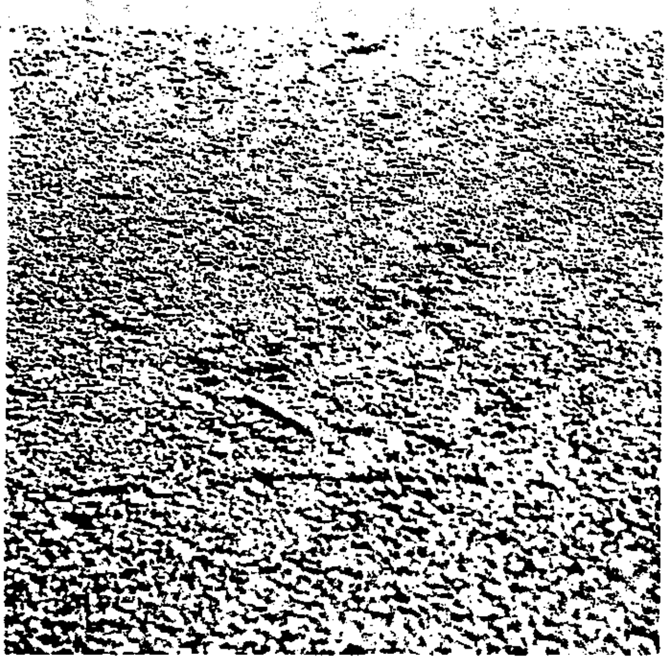
8. Stabilities

No systematic effort was made to determine stabilities (Calif. TM366) of the various mixes used on this project. In the design of the conventional AC, stabilities of 37 to 41 were recorded at the recommended asphalt content. The only stabilities determined for rubberized mixes were for two street samples of the PlusRide material. One was 2, the other 6. Since these seem to be carrying traffic without rutting or bleeding, it must be assumed that these extremely low stabilities do not have the same meaning as with a conventional AC mix. This is another area in which more study is needed.

D. Performance Monitoring

In December, 1983, with snow on the ground, a break in the weather finally permitted the test sections to be photographed to record their appearance when new. So far as could be determined, their appearance was unchanged from when the contractor left the job in early October.

By the end of January, a report of pavement cracking on the project was received. In early February 1984, a project review disclosed considerable loss of surface fines, especially in the wheel tracks, in Segments 7 and 8 (0.20' and 0.18' conventional DGAC [Figure 12]) and fairly severe cracking in the southbound lane of Segment 8 (Figure 13) across the road from TS 8 . One longitudinal crack in the outside wheel track was over an inch wide, and the surface texture had become very coarse. The major transverse cracks were about two feet apart for 300 or 400 feet along the lane, and longitudinal cracks were well developed in the outer wheel track and along the centerline. Oblique photographs were taken to provide a record of the condition at this time. Segments 9 and 10 (0.30' and 0.50' conventional DGAC) showed a slight loss of surface fines, but no cracking.



DGAC (Seg. 7)
Loss of Fines in W.T.

Figure 12

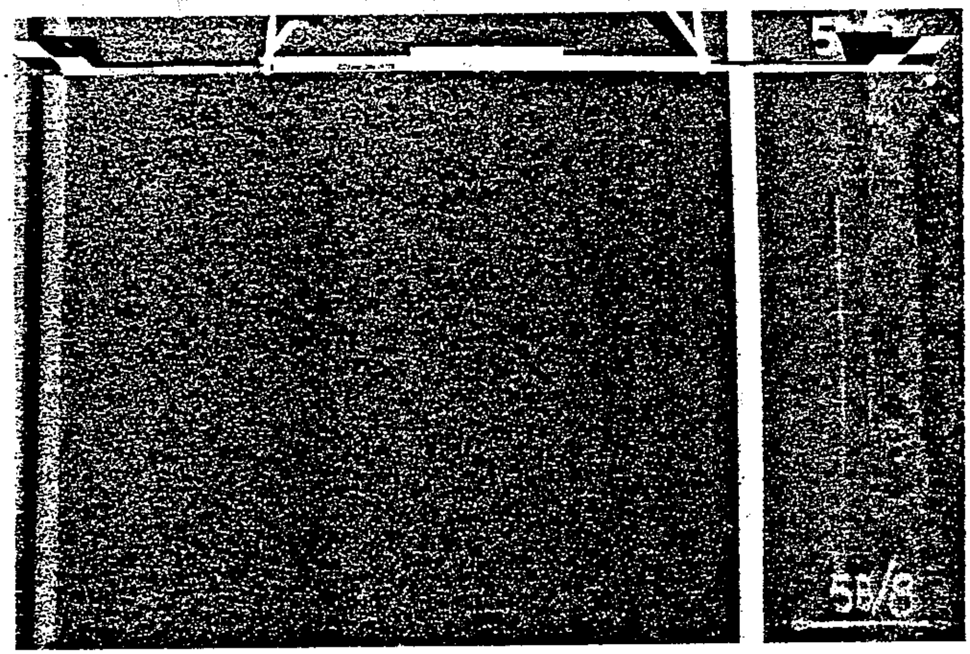
DGAC (Seg. 8)
Cracking

Figure 13

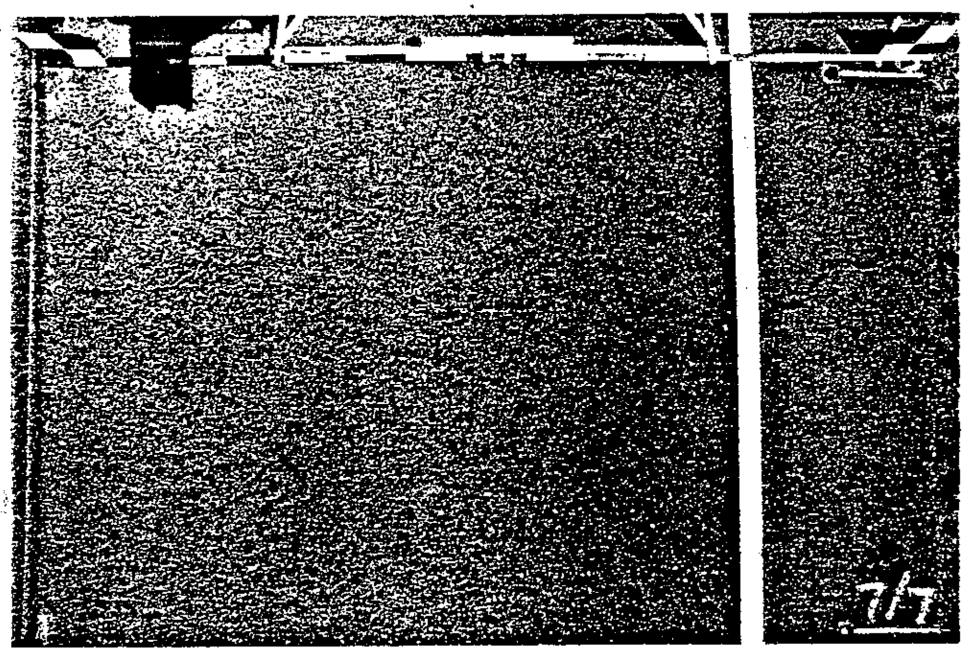
In June of 1984, the test sections were again photographed. The photographs (Figure 14) illustrate:

a) the loss of glaze on the PlusRide DGAC in TS 4 through 6,

b) a coarsened surface texture on the conventional DGAC in TS 7 through 10,



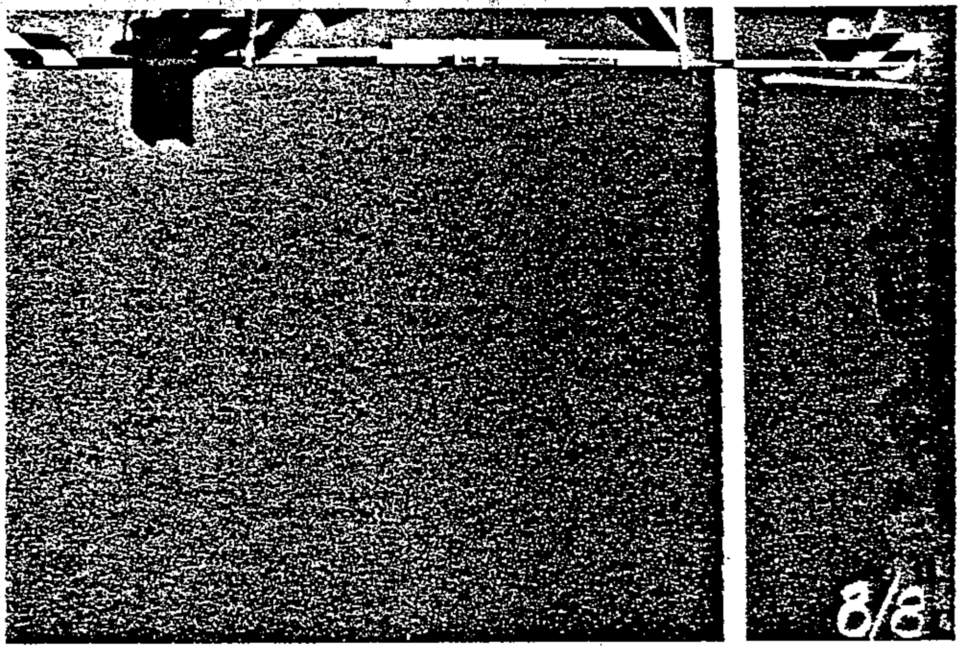
(a) Loss of Glaze on PlusRide



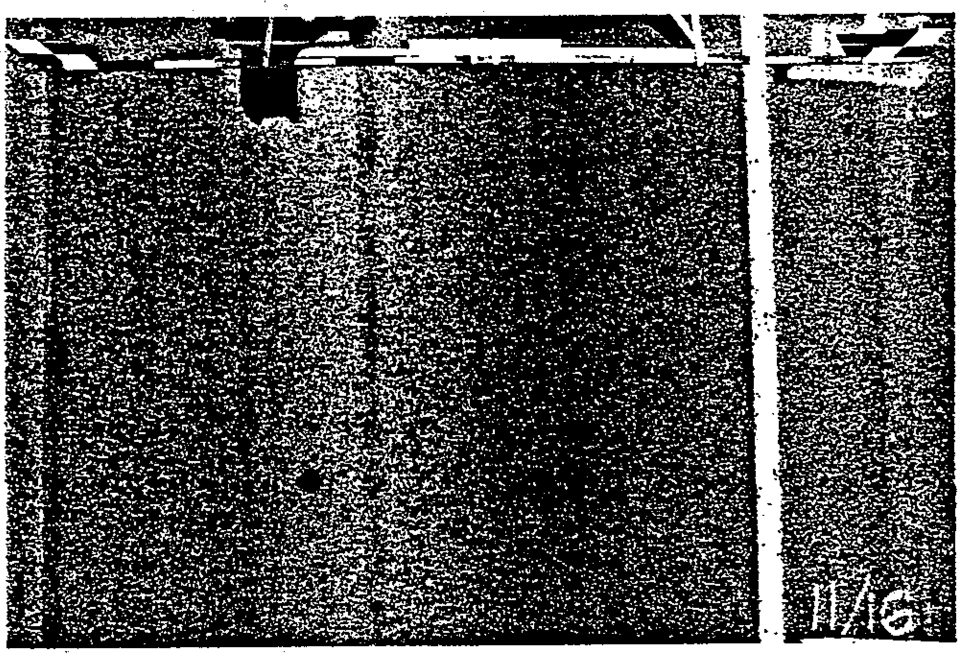
(b) Harsh Texture (DGAC)

Problems Observed in June, 1984

Figure 14



(c) Transverse Crack (0.20' DGAC)



(d) Reflective Cracking (TS 11)

Problems Observed in June, 1984

Figure 14

c) one transverse crack in TS 8 (picture point 8) in the left wheel path, and

d) the pattern of cracking of the old pavement in TS 11 (picture points 15, 16, and 17), beginning to reflect through the double rubberized chip seal, in the right wheel path.

All the rest of the photos show material looking "like new". Cracking in Segment 8 did not appear much changed from February. Most of the winter's precipitation occurred in November and December.

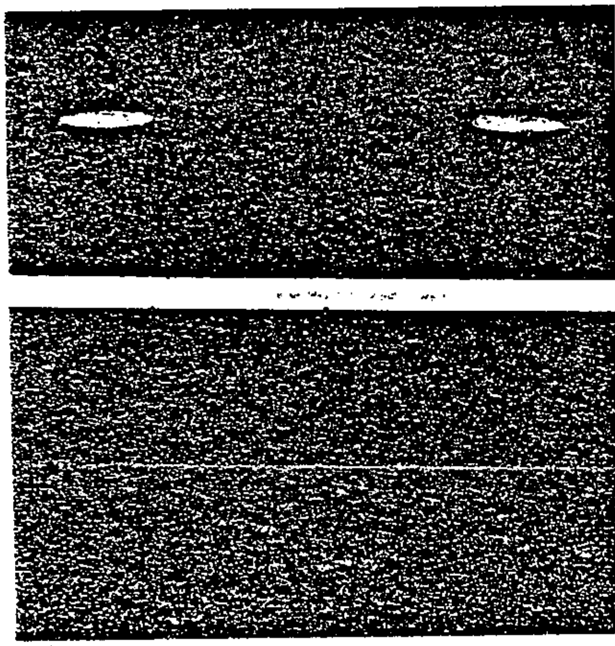
The ARS-DGAC in TS 1 through 3 was in excellent condition, though grass was growing up through it near the outer edges in places. It was found that the edges of the mat were so soft the material could be dug easily with bare fingers. Away from the edges, the mat was much firmer and nowhere could any damage be found, even to the very soft edges. The weather was warm with the recorded high for the day being 80°F.

The PlusRide DGAC had softened somewhat at the edges, but not nearly so much as the ARS-DGAC.

Some hairline reflection cracking was seen in the southbound lane in Segment 13, the single rubberized chip seal, but ironically not in TS 13 itself.

By the latter part of July 1984, there had been a total of 11 days with maximum temperatures of 90° or higher on the project. On two of those days, the temperature reached 96°.

The project was reviewed on July 26, 1984, to see how the rubberized materials were reacting to warm weather. Both the ARS-DGAC and the PlusRide DGAC mats were in excellent condition (Figures 15 and 16).

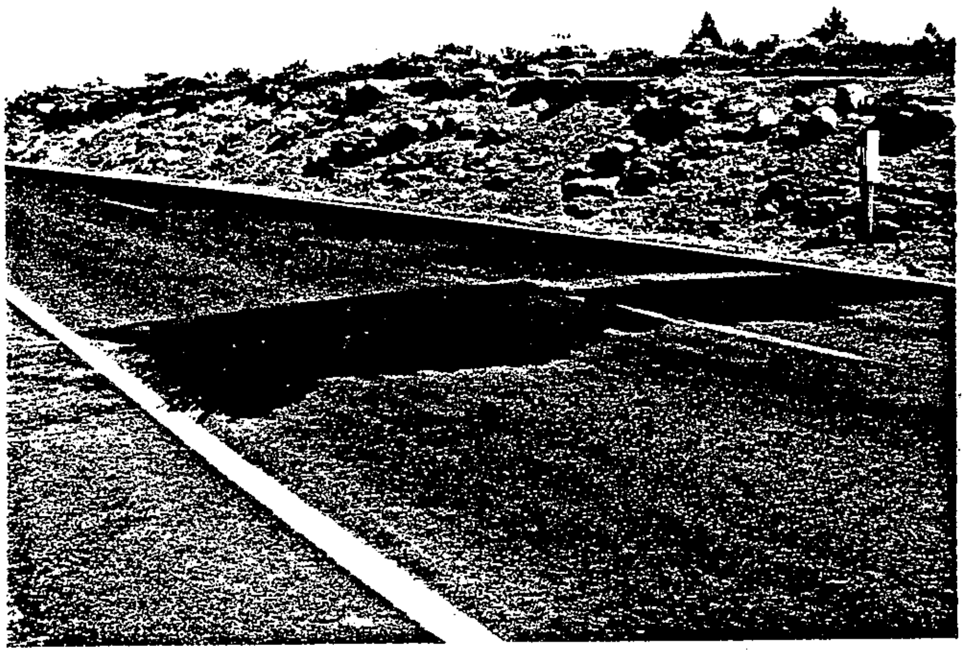


ARS-DGAC (July, 1984)
Figure 15

PlusRide DGAC (July, 1984)
Figure 16

At some of the construction joints in the PlusRide (Segment 4), for about two feet from the joint, there is an area of heavy <u>bleeding</u> (Figure 17). According to the Resident Engineer, the contractor had a problem in this location spreading the AR-4000 paving asphalt used for the tack coat. The rate of application was sometimes too heavy in the first foot or two of the spread. This is, therefore, probably the source of the excess asphalt now coming to the surface. Since the PlusRide DGAC has as low as one or two percent voids, little of the excess can be absorbed.

On July 26, the various mixes were also checked for <u>rutting</u> (Figure 18). The maximum measured was about 1/4 inch in TS 10, the 0.50' thick conventional DGAC control. TS 9, the 0.30' DGAC control, and TS 8, the 0.20 DGAC control, showed about 1/8 inch of rutting. The other test sections showed no rutting. The allowable construction tolerance transverse to highway centerline is 0.02 foot (about 1/4"). The depressions measured were all in the wheel tracks.



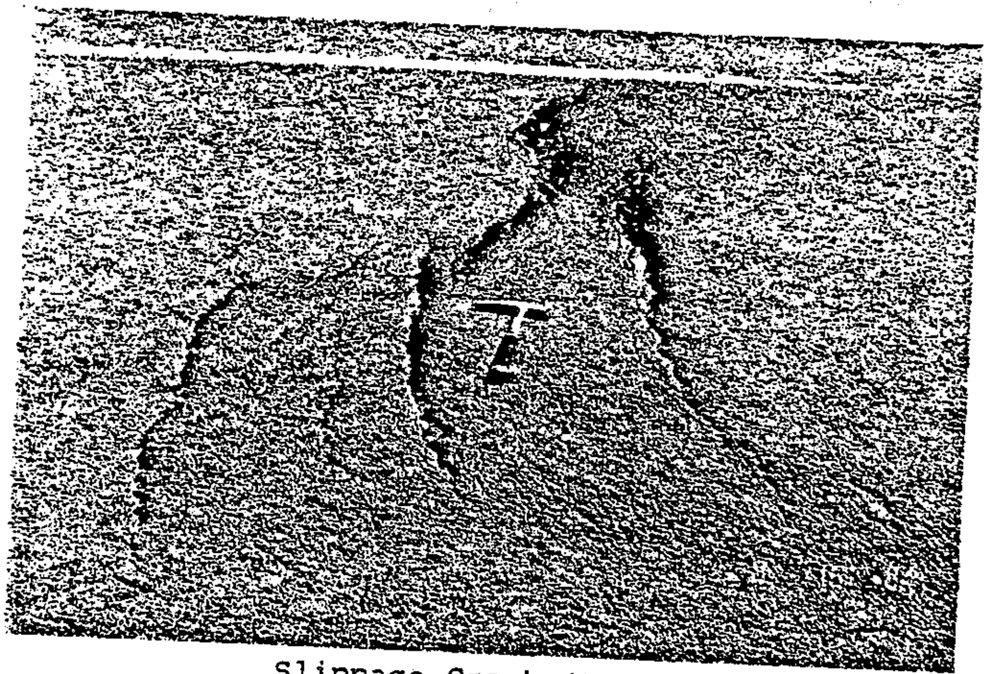
Bleeding at Transverse Joint (PlusRide)

Figure 17

Checking for Rutting (PlusRide)

Figure 18

Slippage cracking has occurred in the southbound lane of Segment 8 (DGAC) at P.M. 98.55. A crescent-shaped crack was visible that measured 1-3/4 inches wide and extended transversely across both wheel tracks (Figure 19). It was convex to the south, downhill, and was apparently the result of vehicle braking on a poorly bonded surface course. Farther south (20' to 30') are several much smaller transverse surface "tears", each about 1/2 inch by 3 feet. They are about 20 feet apart and are in the outer wheel track. There was no sign of this problem elsewhere on the project.



Slippage Crack (DGAC)

Figure 19

SUMMARY

As of July, 1984, this project, in general, is in good condition with all rubber mixtures in better condition than the control sections. The single chip seal, although showing reflection cracking, is in good condition. The chips in the double seal are being deeply imbedded in the wheel tracks and thus an appearance of surface flushing is evident.

The project will be monitored through June of 1987. Each May the test sections will be photographed and tested for deflection (using the Dynaflect) and skid resistance. Cracking will be carefully recorded and evaluated. Because of the high percentage of binder used, the rubberized ACs will be examined closely each fall for rutting and flushing ("bleeding").

APPENDIX A

Contract Specifications for the Various Rubberized Asphalt Products

STATE OF CALIFORNIA
BUSINESS, TRANSPORTATION AND HOUSING AGENCY
DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISIONS

NOTICE TO CONTRACTORS PROPOSAL AND CONTRACT

FOR CONSTRUCTION ON

STATE HIGHWAY

IN

LASSEN COUNTY FROM 0.5 MILE SOUTH OF SECRET VALLEY BRIDGE NO. 7-59 TO 7.0 MILES SOUTH OF RAVENDALE POST OFFICE
DISTRICT 02, ROUTE 395

For use in Connection with Standard Specifications Dated January, 1981, Standard Plans Dated January, 1981, General Prevailing Wage Rates Dated March, 1983, and Labor Surcharge And Equipment Rental Rates.

CONTRACT NO. 02-189504

02-LAs-395-92.0/101.4

Federal Aid Project
F-P395(51)

Bids Open: JUNE 15, 1983

10-1.10 ASPHALT-RUBBER SEAL COAT AND INTERLAYER.-- Asphalt-rubber seal coat and interlayer consisting of a layer or layers of asphalt-rubber binder covered with screenings and conforming to the provisions in Section 37-1, "Seal Coats," of the Standard Specifications and these special provisions shall be placed where shown on the plans.

The types of asphalt-rubber binder and screenings to be applied are shown on the plans and designated in the Engineer's Estimate. When a type of asphalt-rubber binder is neither shown or designated the Contractor may furnish either Type 1 or Type 2 at his option.

The rates of application for the screenings and asphalt-rubber binder for the seal coats and intelayers shall be within the ranges specified in the following table. The exact rates will be determined by the Engineer.

Type of Application		Rate of Application per Square Yard	
	Size of Screenings	Screenings (pounds)	Asphalt-Rubber Binder (Gallon)
Seal Coat	3/8" x No. 6	35 to 40	0.55 to 0.60
Double Seal Coat			
1st application	1/2" x No. 4	30 to 40	0.45 to 0.55
2nd application	1/4" x No. 10	22 to 32	0.35 to 0.45
Interlayer	3/8" x No. 6	30 to 35	0.57 to 0.63

MATERIALS.--The grades of paving asphalt for asphalt-rubber binder Type 1 and Type 2 will be determined by the Engineer based on the suppliers recommendations.

The method and equipment for combining the rubber, asphalt and diluent or extender oil shall be so designed and accessible that the Engineer can readily determine the percentages, by weight, of each of the materials being incorporated into the mixture.

A Certificate of Compliance shall be furnished for the rubber, verifying the conformance of the rubber to these special provisions, as specified in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications.

ASPHALT-RUBBER BINDER (TYPE 1).--Granulated rubber for asphalt-rubber binder (Type 1) shall consist of a minimum of 80% by weight of vulcanized rubber. The rubber shall consist of one or a blend of the gradings indicated below with the rubber or blend selected based on laboratory testing by the asphalt-rubber supplier.

Sieve Sizes	Percentage Passing Coarse	Medium	Fine
No. 8	100	--	--
No. 10	95-100	--	--
No. 16	--	100	100
No. 30	0-10	60-90	95-100
No. 50	0-5	0-20	30-60
No. 80	--	0-5	15-35
No. 200	--	--	0-10

The sieves shall comply with the requirements of AASHTO Deisgnation: M 92.

The individual granulated rubber particles, irrespective of diameter, shall not be greater in length than 0.250" for course and 0.125" for medium and fine gradings.

The combined granulated rubber shall have a specific gravity of 1.15$\pm$ 0.05 and shall be free of loose fabric, wire and other contaminants except that up to 4% (by weight of rubber) calcium carbonate of talc may be added to prevent rubber particles from sticking together.

The percentage of paving asphalt shall be from 74% to 80% and the percentage of rubber 20% to 26%, both by weight of the total asphalt-rubber mixture. The exact rates will be determined by the Engineer.

The temperature of the paving asphalt shall be between 350° F. and 425° F. at the time rubber is added. The asphalt and rubber shall be combined and mixed together in a blender unit to produce a homogeneous material.

The asphalt-rubber mixture shall be mixed for a minimum of 30 minutes.

The diluent shall be added to the asphalt-rubber mixture at a rate of from 0% to 7.5%, by volume, the exact rate will be determined by the Engineer.

The diluent shall be a solvent with an initial boiling point of at least 340° F. when testing in accordance with ASTM Designation: D 86.

The temperature of the asphalt-rubber mixture shall be not less than 325° F. during the mixing process.

The asphalt-rubber mixture shall be spread as soon as possible after reaching the desired consistency and shall not be held at temperatures over 325° F. for more than four hours.

The asphalt-rubber mixture shall not be applied after it has been retained for more than 48 hours.

ASPHALT-RUBBER BINDER (TYPE 2).--Rubber for asphalt-rubber binder (Type 2) shall be a blend of 20% to 40% powered reclaimed devulcanized rubber and 60% to 80% ground vulcanized rubber. The exact proportions will be determined by the Engineer.

Gradation of the rubber shall be such that 100% will pass a No. 10 sieve and no particle shall be longer than 1/4" in length.

When 40 to 50 grams of rubber retained on the No. 30 sieve are added to a tight set 6" rubber mill, the material shall band on the mill roll in one pass.

Extender oil shall be added to the paving asphalt at a rate of from 2% to 15%. The percentage of paving asphalt shall be from 78% to 82% and the percentage of rubber from 18% to 22%, both by weight of the total asphalt-rubber mixture. The exact rates will be determined by the Engineer.

The temperature of the paving asphalt shall be between 375° F. and 425° F. at the time rubber is added.

The asphalt and rubber shall be combined and mixed together in a blender unit to produce a homogeneous mixture.

The asphalt-rubber mixture shall be mixed for a minimum of 45 minutes and until such time as a product is produced with the following properties:

Vicosity at 400° F.	1,000 cps.	Max.
Softening Point (R & B)	120° F.	Min.
Flex Temperature (90° Bend Test)	20° F.	Max.

The asphalt-rubber mixture shall be spread as soon as possible after reaching the desired consistency and shall not be held at temperatures over 400' F. for more than four hours.

The asphalt-rubber mixture shall not be applied or used as a binder after it has been retained for more than 48 hours.

SCREENINGS.--Screenings for the asphalt rubber interlayer and seal coat shall be preheated to a temperature between 290° F. and 350° F. After preheating, screenings shall be precoated with

0.33 of one percent of paving asphalt. Canvas or similar covers that completely cover each load of screenings shall be used to minimize temperature drop of the exposed material. Screenings shall be spread at a temperature of not less than 225° F.

Stockpiling of screenings after preheating and precoating will not be permitted.

EQUIPMENT.--The equipment used by the Contractor shall include the following:

1. A self-propelled power broom or brooms capable of cleaning the existing pavement and removing loose screenings without dislodging screenings set in the asphalt-rubber mixture. A gutter broom or steel-tined broom shall not be used.
2. Three pneumatic-tired rollers conforming to the requirements specified in Section 39-5.02, "Compacting Equipment," of the Standard Specifications.
3. Self-propelled chip spreader conforming to the requirements specified in Section 37-1.06, "Spreading Cover Material," of the Standard Specifications.
4. A self-propelled distributor truck or truck equipped with mixing equipment capable of producing a homogeneous mixture of rubber and asphalt and spreading the mixture at the specified rate.

SPREADING.--The surface shall be cleaned of all dirt and loose material before applying the asphalt-rubber mixture.

A paint binder of asphaltic emulsion shall be applied to the existing pavement.

The spread rate shall be between 0.03 and 0.06 gallons per yard as determined by the Engineer.

Asphalt-rubber seal coat, interlayer or double seal coat shall not be placed when the atmospheric temperature is below 60° F. or above 100° F.

Immediately following the application of the asphalt-rubber binder for seal coat, interlayer or each layer of double seal coat, it shall be covered with screenings.

The chip spreader shall never be more than 50' behind the distribution truck unless otherwise ordered by the Engineer.

COMPACTING.--Initial rolling shall consist of a minimum of one complete coverage with one or more pneumatic-tired rollers and shall begin immediately behind the chip spreader. The distance between the rollers and the chip spreader shall not exceed 200' at any time during chip spreading operations. A minimum of 3 complete coverages as defined in Section 39-6.03, "Compacting," of the Standard Specifications with a pneumatic-tired roller, after the initial coverages, shall be made on the asphalt-rubber seal coat, interlayer and second application of double seal coat. The first application of double seal coat shall receive 6 such coverages.

MISCELLANEOUS.--Loose screenings shall be removed by light brooming before asphalt concrete is placed over the interlayer.

All joint edges shall be swept clean of overlapping cover material prior to application of the adjacent asphalt-rubber mixture. All reasonable precautions shall be taken to avoid skips and overlaps at joints. All defects shall be corrected. Correction of any such defects will be at the Contractor's expense. All transverse joints shall be made by placing building paper over the ends of the previous applications, and the joining application shall start on the building paper. The paper shall be removed and disposed of.

Trucks hauling screenings shall be kept clear of the freshly placed screenings unitl ready to dump screenings into the chip spreader.

Excess screenings shall be removed and disposed of as specified in the eleventh paragraph of Section 37-1.07, "Finishing," of the Standard Specifications. Removal of excess screenings shall be completed before uncontrolled traffic is permitted on the seal coats.

MEASUREMENT.--Asphalt-rubber binder for seal coats and interlayer will be measured by the ton determined by the weight of paving asphalt and rubber incorporated in the mixture. Screenings will be measured by the ton, measured after preheating and precoating with paving asphalt.

PAYMENT.--The Contractor prices paid per ton for the various types of asphalt-rubber binded and per ton for the various sizes of screenings shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals, and for doing all the work involved in applying asphalt-rubber seal coats and interlayer, including preheating and precoating screenings (including paving asphalt), and furnishing and applying diluent or extender oil, complete in place, as shown on the plans, as specified in these special provisions and the Standard Specifications, and as directed by the Engineer.

C6 "Loose Gravel" and W6 (35) speed advisory signs shall be furnished and placed adjacent to both sides of the traveled way where screenings are being spread on a traffic lane. The first C6 sign in each direction shall be placed where traffic first encounters loose screenings, regardless of which lane the screenings are being spread on. The signs shall be placed at maximum 2,000-foot intervals along each side of the traveled way and at all public roads or streets entering the seal coat area as directed by the Engineer.

Where screenings are being spread on a traffic lane, C6 "Loose Gravel" and W6 (35) speed advisory signs shall be furnished and placed adjacent to the outside edge of the traveled way nearest to the lane being worked on. The first C6 sign shall be placed where the screenings begin with respect to the direction of travel on that lane. The signs shall be placed at maximum 2,000-foot intervals along the edge of traveled way and at on-ramps and public roads or streets entering the seal coat area as directed by the Engineer.

The C6 and W6 signs shall be maintained in place at each location until final sweeping or brooming of the seal coat surface at that location is performed. When no longer required, the signs shall become the property of the Contractor and shall be removed from the site of the work. The C6 and W6 signs shall conform to the requirements in "Construction Area Signs" of these special provisions, except for payment. The signs shall be set on stationary or portable supports with the W6 below the C6.

Full compensation for furnishing, placing, maintaining, and removing C6 and W6 signs and stationary or portable supports for the signs shall be considered as included in the contract prices paid per ton for the various items of asphalt-rubber binder and screenings that are provided and involved and no separate payment will be made therefor.

10-1.11 ASPHALT CONCRETE.--Asphalt concrete shall be Type A, Type B asphalt concrete (leveling), asphalt concrete with asphalt-rubber binder and asphalt conrete (Plus Ride) and shall conform to the provisions in Section 39, "Asphalt Concrete," of the Standard Specifications and these special provisions.

The fourth paragraph in Section 39-3.03B(2), "Proportioning for Continuous Pugmill Mixing or Drier-Drum Mixing with Cold-Feed Control," of the Standard Specifications is amended to read:

> Asphalt meters and aggregate belt scales used for proportioning asphalt and aggregates shall be equipped with rate-of-flow indicators to show the rates of delivery of asphalt and aggregate, and resettable totalizers so that the

total amounts of asphalt and aggregate introduced into the mixture can be determined.

Before adding the paving asphalt binder, the temperature of the aggregate shall be not less than 290° F. nor more than 325° F.

Asphalt concrete shall be placed only when the surface temperature of the area to be paved is above 45° F.

In addition to the aggregate requirements listed in Section 39, "Asphalt Concrete," of the Standard Specifications, the combined aggregates shall conform to the following quality requirement when mixed with paving asphalt Grade AR 4000 in the amount of asphalt determined to be optimum by California Test 367:

Test	California Test	Requirement
Surface Abrasion	360, Method A	Loss not to exceed 10 grams

The fine aggregate shall also conform to the following quality requirement:

Test	California Test	Requirement
Durability Index (D_f)	229	50 min.

Limestone aggregates shall not be used in the final layer of asphalt concrete surfacing.

In addition to the requirements in Section 39-5.01, "Spreading Equipment," of the Standard Specifications, asphalt paving equipment shall be equipped with automatic screed controls and a sensing device or devices.

When placing asphalt concrete to lines and grades established by the Engineer, the automatic controls shall control the longitudinal grade and transverse slope of the screed. Grade and slope references shall be furnished, installed and maintained by the Contractor. Should the Contractor elect to use a ski device, the minimum length of the ski device shall be 30 feet. The ski device shall be a rigid one piece unit and the entire length shall be utilized in activating the sensor.

When placing the initial mat of asphalt concrete on existing pavement, the end of the screed nearest the centerline shall be controlled by a sensor activated by a ski device not less than 30 feet long. The end of the screed farthest from centerline shall be controlled manually. When paving contiguously with previously placed mats, the end of the screed adjacent to the previously placed mat shall be controlled by a sensor that responds to the grade of the previously placed mat and will reproduce the grade in the new mat within a 0.01-foot tolerance. The end of the screed farthest from the previously placed mat shall be controlled in the same manner as when placing the initial mat.

Should the methods and equipment furnished by the Contractor fail to produce a layer of asphalt concrete conforming to the requirements, including straightedge tolerance, of Section 39-6.03, "Compacting," of the Standard Specifications, the paving operations shall be discontinued and the Contractor shall modify his equipment or furnish substitute equipment.

Should the automatic screed controls fail to operate properly during any day's work, the Contractor may use manual control of the spreading equipment for the remainder of that day, however, the equipment shall be corrected or replaced with alternative automatically controlled equipment conforming to the requirements in this section before starting another day's work.

The area to which paint binder has been applied shall be closed to public traffic. Care shall be taken to avoid tracking binder material onto existing pavement surfaces beyond the limits